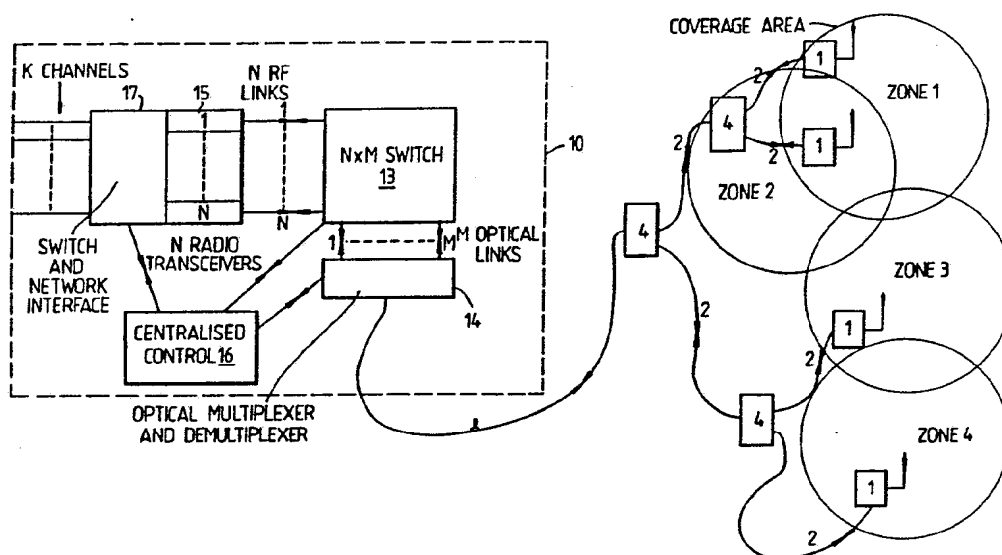




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁵ : H04Q 7/04, H04B 7/26 H04M 1/72	A1	(11) International Publication Number: WO 90/05432 (43) International Publication Date: 17 May 1990 (17.05.90)
(21) International Application Number: PCT/GB89/01341 (22) International Filing Date: 10 November 1989 (10.11.89) (30) Priority data: 8826476.7 11 November 1988 (11.11.88) GB (71) Applicant (for all designated States except US): BRITISH TELECOMMUNICATIONS PUBLIC LIMITED COMPANY [GB/GB]; 81 Newgate Street, London EC1A 7AJ (GB). (72) Inventors; and (75) Inventors/Applicants (for US only) : MOTLEY, Andrew, James [GB/GB]; Hillcroft, Martlesham Hill, Woodbridge, Suffolk IP12 4SF (GB). CHADNEY, Anthony, Gerard [GB/GB]; 97 Hervey Street, Ipswich, Suffolk IP4 2ET (GB). (74) Agent: BUTTRICK, Richard; British Telecommunications public limited company, Intellectual Property Unit, 151 Gower Street, London WC1E 6BA (GB).		(81) Designated States: AT (European patent), AU, BE (European patent), CH (European patent), DE (European patent), DK, FI, FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), NO, SE (European patent), US. Published <i>With international search report.</i>

(54) Title: COMMUNICATIONS SYSTEM**(57) Abstract**

A communications system has a base centre with radio transceivers (15) for providing a number of radio frequency (RF) communications links and a plurality of fixed radio ports (1) through which RF signals can be transmitted and received over the air. A fibre optic network (2, 4) interconnects the RF transceivers (15) and the fixed radio ports (1), and carries the RF signals by means of optical signals. There is a plurality of radio/optical interfaces by which RF signals can be modulated onto and demodulated from one or more optical signals, between the RF transceivers and the fibre optic network, and between the fibre optic network and the fixed radio ports. A matrix switch (13) selectively interconnects the transceivers and the radio ports through the fibre optic network.

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COMMUNICATIONS SYSTEM

The present invention relates to a communications system, and in particular to a system for interconnecting mobile radio (RF) units to a fixed network or system e.g. PSN, ISDN, LAN or PBX.

At present, for example, in a cellular radio system mobile radio (RF) units communicate with fixed base stations which have radio transceivers that are connected to a switching control centre which is in turn coupled to the PSTN. In the proposed Telepoint system, cordless telephones (CTs) will be able to access the PSTN via radio communication with fixed base stations equipped with radio transceivers which are directly connected to the PSTN. In both these examples radio transceivers and base stations proliferate in the connection between the mobile user and the PSTN, or other network. These systems are therefore complicated and expensive. Future systems will want to provide improved coverage including the provision of many small radio "cells", and hence many base stations and radio transceivers will be required.

Difficulties in finding appropriate base station sites and the costs of equipping them may make such conventional developments impracticable; certainly they reduce the commercial attractiveness of such projects. The present invention seeks to provide a communication system of simplified structure and improved performance.

According to a first aspect the invention provides a communications system comprising: a base centre having one or more radio transceivers for providing a number of radio frequency (RF) communications links; a plurality of fixed radio ports through which RF signals can be transmitted and received over the air; a fibre optic network for

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interconnecting the RF transceivers and the fixed radio ports, and for carrying the RF signals by means of optical signals; a plurality of radio/optical interfaces by which RF signals can be modulated onto and demodulated from one or more optical signals, which interfaces are between the RF transceivers and the fibre optic network, and between the fibre optic network and the fixed radio ports.

The present invention also provides a communications system comprising: a base centre having one or more radio transceivers for providing a number of radio frequency (RF) communications links; a plurality of fixed radio ports through which RF signals can be transmitted and received over the air; a fibre optic network for interconnecting the RF transceivers and the fixed radio ports, and for carrying the RF signals by means of optical signals; a plurality of radio/optical interfaces by which RF signals can be modulated onto and demodulated from one or more optical signals, which interfaces are between the RF transceivers and the fibre optic network, and between the fibre optic network and the fixed radio ports; and a matrix switch for selectively interconnecting the transceivers and the radio ports through the fibre optic network.

The present invention allows for centralisation of transceivers into base centres, and the consequent advantages in terms of technical and commercial gain, by having the transceivers selectively connectable through the fibre optic network to the RF ports.

The RF Communication linking may for example, be time division multiplexed (TDM) or frequency division multiplexed (FDM).

A preferred embodiment of the invention will now be described by way of example and with reference to the accompanying drawings, wherein:

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- Figure 1 is a schematic block diagram of a communications system according to a preferred embodiment of the invention;

- Figure 2a is a schematic block diagram of an optical matrix switch which can form part of the preferred embodiment;

- Figure 2b is a schematic block diagram of an RF matrix switch which can form part of the preferred embodiment; and

- Figure 3 is a schematic view of another embodiment of the invention.

The preferred embodiment illustrated in Figure 1 is a multi-user, area coverage radio distribution system using an optical network 2,4 to link the fixed radio distribution ports 1 to a centralised radio and other signal processing base centre 10. An important feature of the system is the use of an optical carrier modulated, e.g. amplitude modulated, with a radio frequency (RF) signal.

In both the base centre 10 and RF ports 1 there are, arranged in different ways, radio/optical interfaces which can place an RF signal onto an optical carrier or conversely recover an RF signal from an optical carrier. The modulation of the optical carrier may be achieved by driving a suitable laser device with the input RF signal so that output of the laser is effectively intensity or amplitude modulated by the RF signal. With this method, a suitable optical detector receiving the amplitude modulated optical signal can produce a direct RF output. In the present specification, the term radio/optical interface is used in this context.

The radio ports 1 each have a radio/optical interface which receives and transmits radio carriers from and to roaming radio equipment. The radio carriers to be

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sent/received from the centralised location are placed onto/taken off an optical carrier, e.g. as described above. The optical network 2,4 linking the radio ports 1 to the base centre 10 is generally conventional, having optical links carrying RF carrier/carriers on optical carrier/carriers. Each optical link is shown as bidirectional. However, separate links could be provided for each direction. Within the optical system are optical multiplexers/demultiplexers (M+D) 4. Each multiplexer concentrates a number of optical carriers, say X, onto a fewer number of optical links than X. The demultiplexers splits a number of optical carriers onto individual optical links.

At the base centre 10 the optical system 2,4 is connected to an optical multiplexer and demultiplexer (M+D) 14. The M+D 14 is connected (illustratively) by M optical lines to an NxM matrix switch 13, which will be described below in more detail. The NxM matrix switch 13 has N RF links to a number (N) radio transceivers 15. The radio transceivers 15 are connected through a switch 17 to a number (K) channels of another network which may be ISDN, cellular, LAN, PBX etc. K may be greater than or equal to N. Also in the base centre 10, a central unit 16 is connected to the switch 17, NxM matrix switch, and M+D 14 to control optical, RF, and baseband routing and switching, and co-ordinate the allocation of RF carriers and channels in conjunction with mobile equipment.

A central part of the base centre 10 is the NxM matrix switch 13. This multiplexes any of the N radio carriers onto any of the M optical transmission lines, i.e. none, one or more of the radio carriers may be on any one of the optical carriers at any one time. The NxM matrix switch 13 may be configured in one of two ways, as shown in Figures 2a and 2b. In each case, the radio/optical

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interface places the RF carriers to be transmitted from the central transceivers onto the optical carrier(s) and takes off, from the optical carrier(s), the RF carriers to be received by the central transceivers. The switching may be optical (Figure 2a), in which case the radio/optical interface is on the radio "side" of the switch, or the switch may be a radio (RF) matrix switch (Figure 2b), in which case the radio optical interface is on the optical system "side" of the switch. In either case, the overall result is that the N radio lines can be multiplexed onto the M optical lines.

The advantages of the system of the preferred embodiment are profound. A user can access the external network through any of the radio ports 1 with a suitable RF transceiver, e.g. a cordless telephone (CT), and be connected to a free one of the N transceivers 15. Provided the RF capacity was available, all N transceivers could be employed in calls to/from a particular one of the radio ports 1, or as would be more likely, the usage of the transceivers would be distributed among the radio ports of the system. Here lies a key advantage of the system: the centralisation of the radio transceivers. In the present system the radio transceivers are centralised, allowing more economic use and facilitating maintenance etc. Other significant advantages include the possibility of handover between ports covering different zones or areas, by simply switching between optical carriers, i.e. by switching within the NxM matrix switch 13. Also the use of diversity can easily be achieved centrally through switching or combining links to 2 or more ports, to improve performance of mobiles covered by those ports. Further, advantageous use of the RF system can be achieved because any of the carriers allocated to the service, rather than a given subset, can be dynamically assigned by

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the centralised base, to a given zone or cell. Thus an RF carrier may be allocated to both zone 1 and zone 4, but to different users. At another time, RF carrier may be assigned to just zone 3. The total number of users may remain more or less constant for the whole system, but user density within the system may vary. For example, all the users may shift from zone 1 down to zone 4, with all the central transceivers continually active. If transceivers were placed remotely in each of the zones, the same number of transceivers as that at a centrallocation would be required in each of the zones to meet the peak traffic demand during the day, even though they could remain idle for much of the time. Four times the number of transceivers of the centralised configuration would then be required for the system of Figure 1, hence the improved trunking performance of the centralised scheme, minimising the cost of providing transceivers, the quantity of equipment in the field and affording a potential reduction in maintenance and installation costs.

Handover requires a change of base transceiver as a mobile transits zones. This need no longer be necessary as the switch, block 3, simply switches the active transceiver for a given mobile from one zone to another as the mobile makes the transition. Thus handover break is reduced to a potentially very short optical or RF switch time compared to the much longer period required to switch between transceivers.

The spectrum efficiency of many radio distribution systems are increased if the RF transmissions within the system are synchronised. This is difficult if transceivers are spread over several locations, but more straightforward when they are centralised.

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An alternative embodiment of the invention is shown in Figure 3 and is very similar to that of Figure 1, except that the optical system does not incorporate multiplexing/demultiplexing. Thus there are no M+Ds 4 and the M outputs of NxM switch 13 are connected directly to the radio ports 1. There is therefore a permanent 1 to 1 correspondence between the optical lines in the NxM switch 13 and the radio ports 1.

The embodiment of the invention described is based on the use of frequency division multiple access, where each communications link is on a separate radio frequency. As an alternative, time division multiple access could be used, where each communication link exists on separate time slots on a single radio channel. In this case there may still be multiple transceivers in the base centre 10 to cope with the traffic demand and hence provide frequency/timeslot reuse at the radio distribution ports 1. The connection from the transceivers 15 to the matrix switch 13 will then be by N radio links with P timeslots each, making NxP links in total to the matrix switch 13 from the transceivers 15. An extension of this approach is the possibility of a hybrid time and frequency division access system, with multiple radio carriers and several timeslots on each.

An example of a form of an RF switch is shown in Figure 4. The figure shows the RF matrix switch in a three distribution point system demonstrator. The RF matrix switch interconnects the four radio transceivers 51 (with their associated isolator circuits 52) to the three circuits each of which feeds a distribution point via a pair of fibres. Bi-directional RF connections for all the combinations of base unit and D.P. are made via switches that allow either through connection or isolation of the connection path. These switches are under computer

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control.

The signals from/to the radio transceiver 51 are split/combined in four 3 way combiners 53 (these are actually 4 way combiners with the spare output feeding to the scanning receiver 52) with each output/input passing through a switch that can isolate that output/input. From the switches the signals go to the inputs of one of the three 4 way combiners 55 and hence to/from the D.P.s via one of the three RF/optical interfaces 56.

These switches are under microprocessor control and allow the RF matrix to switch any transceiver to any combination of the distribution points and conversely a distribution point to any combination of the transceivers. Thus a base unit can feed all the distribution points simultaneously then by changing the switches feed only one distribution point.

Two examples of the elements for optical switch and shown in Figure 5. There are two basic technologies; (i) Bulk Optic Devices and (ii) Guided Wave Devices.

A bulk optic switch element, shown in Figure 5(a), uses mechanical or physical reorientation of the optical path to achieve the switching of the incoming optical signals between output ports. An example of this type of switch is presented below for a single input switchable between two outputs. Other switch configurations using this as a basic building block facilitate 2x2 and 2x4 switches.

A guided wave device switch element, shown in Figure 5(b), uses the electro-optic effect to change the optical propagation characteristics of switch waveguides through the application of electric fields. An example of this device type is the Mach Zender Interferometer (MZI) shown in Figure 5(b). This type of switch can be extended from a simple 2x2 to a non-blocking 8x8 switch matrix.

CLAIMS

1. A communications system comprising: a base centre having one or more radio transceivers for providing a number of radio frequency (RF) communications links; a plurality of fixed radio ports through which RF signals can be transmitted and received over the air; a fibre optic network for interconnecting the RF transceivers and the fixed radio ports, and for carrying the RF signals by means of optical signals; a plurality of radio/optical interfaces by which RF signals can be modulated onto and demodulated from one or more optical signals, which interfaces are between the RF transceivers and the fibre optic network, and between the fibre optic network and the fixed radio ports.

2. A communications system comprising: a base centre having one or more radio transceivers for providing a number of radio frequency (RF) communications links; a plurality of fixed radio ports through which RF signals can be transmitted and received over the air; a fibre optic network for interconnecting the RF transceivers and the fixed radio ports, and for carrying the RF signals by means of optical signals; a plurality of radio/optical interfaces by which RF signals can be modulated onto and demodulated from one or more optical signals, which interfaces are between the RF transceivers and the fibre optic network, and between the fibre optic network and the fixed radio ports; and a matrix switch for selectively interconnecting the transceivers and the radio ports through the fibre optic network.

- 10 -

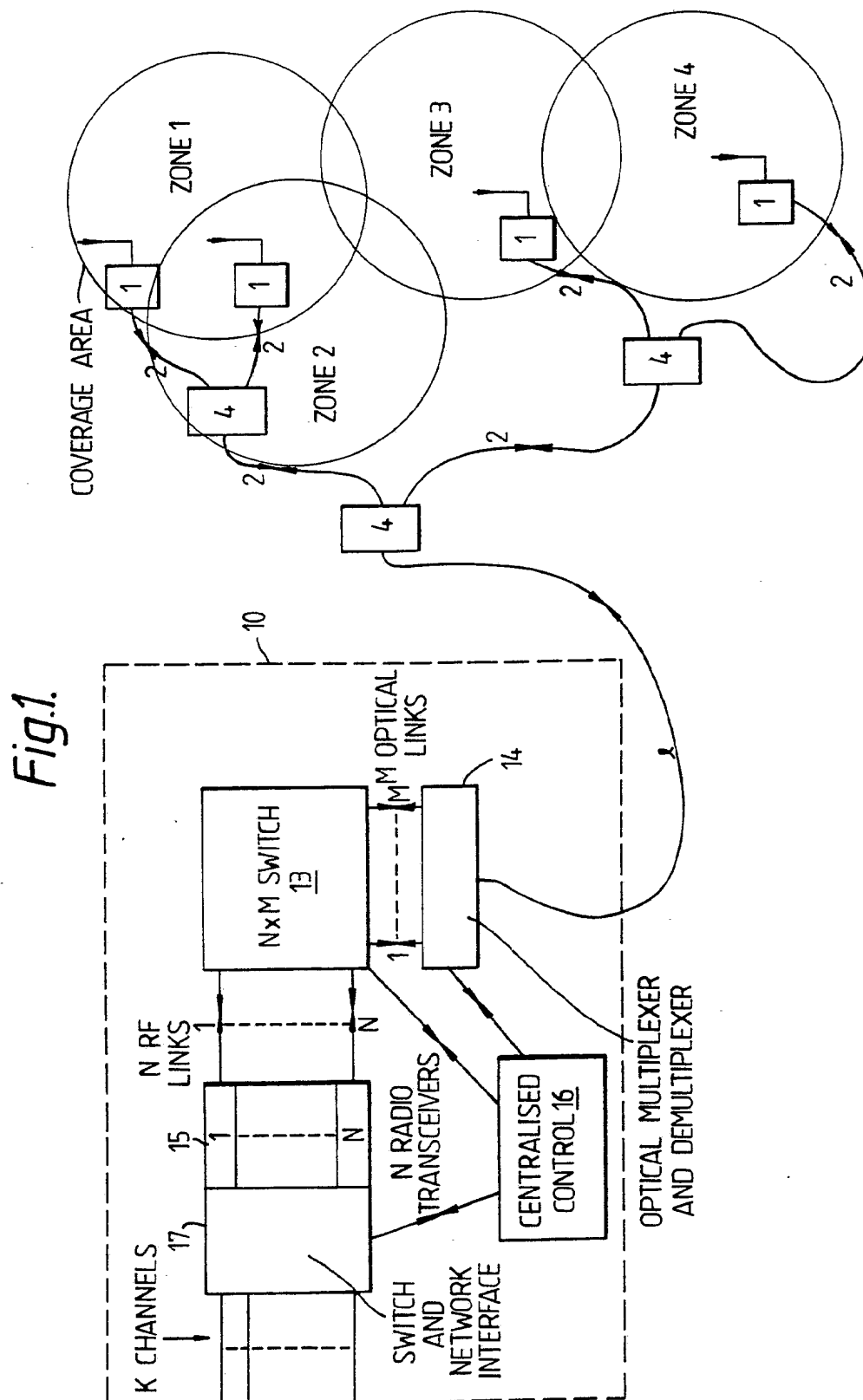
3. A communications system as claimed in claim 2 wherein the RF links are frequency division multiplexed.
4. A communications system as claimed in claim 2 wherein the RF links are time division multiplexed.
5. A communications system as claimed in claim 2, 3 or 4, wherein there is means for combining RF signals to or from one or more of the RF ports.
6. A communications system as claimed in any one of claims 2 to 5 wherein the matrix switch is for switching optical signals and between the optical matrix switch and the one or more RF transceivers there are one or more RF/optical interfaces.
7. A communications system as claimed in any of claims 2 to 5 wherein the matrix switch is for switching RF signals, and between the RF matrix switch and the fibre optic network there are one or more RF/optical interfaces.
8. A communications system as claimed in any preceding claim wherein there is multiplexing/demultiplexing of the optical signals in the fibre optic network.
9. A communications system as claimed in any preceding claim wherein the fibre optic network incorporates wavelength routing of optical signals.
10. A communication system as described in any preceding claim which call handover is between radio ports is controlled in the base centre through switching the radio transceiver from one radio port to another radio port by the matrix switch.

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11. A communication system as claimed in any preceding claim which diversity operation is provided by combining or switching between two or more radio points in the matrix switching.

12. A communication system as claimed in any preceding claim which dynamic channel allocation is controlled in the base centre.

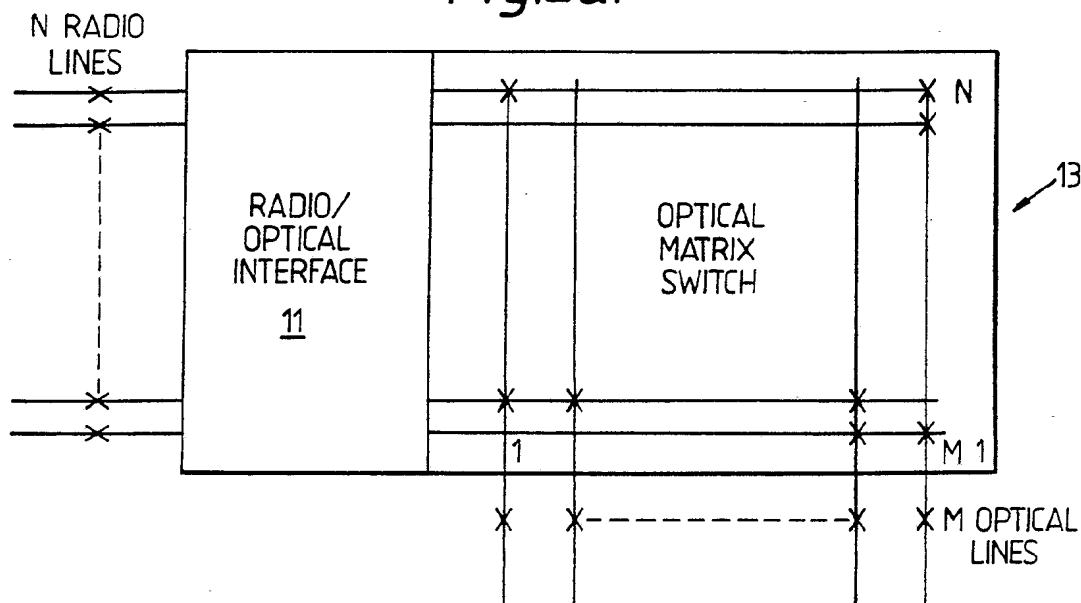
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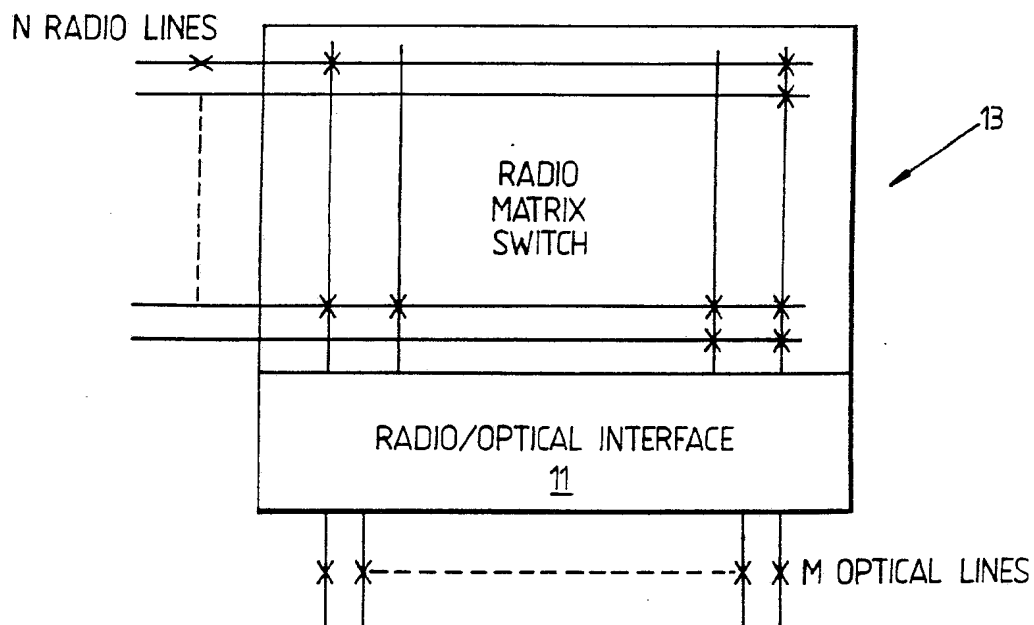
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Fig.2a.



* DENOTES CONNECTION OF A COLUMN TO A ROW THUS COLUMN M IS SHOWN CONNECTED TO ROWS 1, N-1 AND N

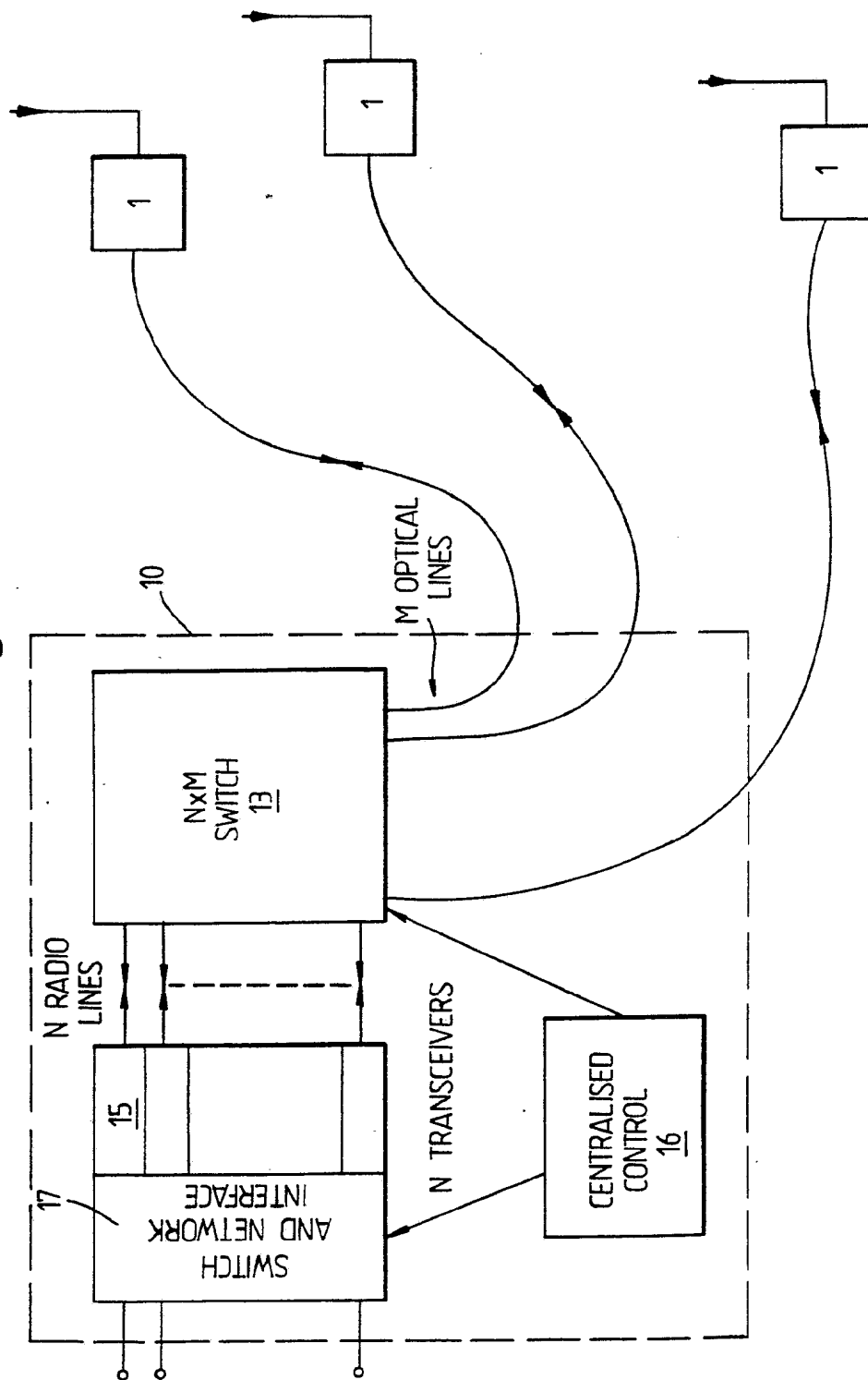
Fig.2b.



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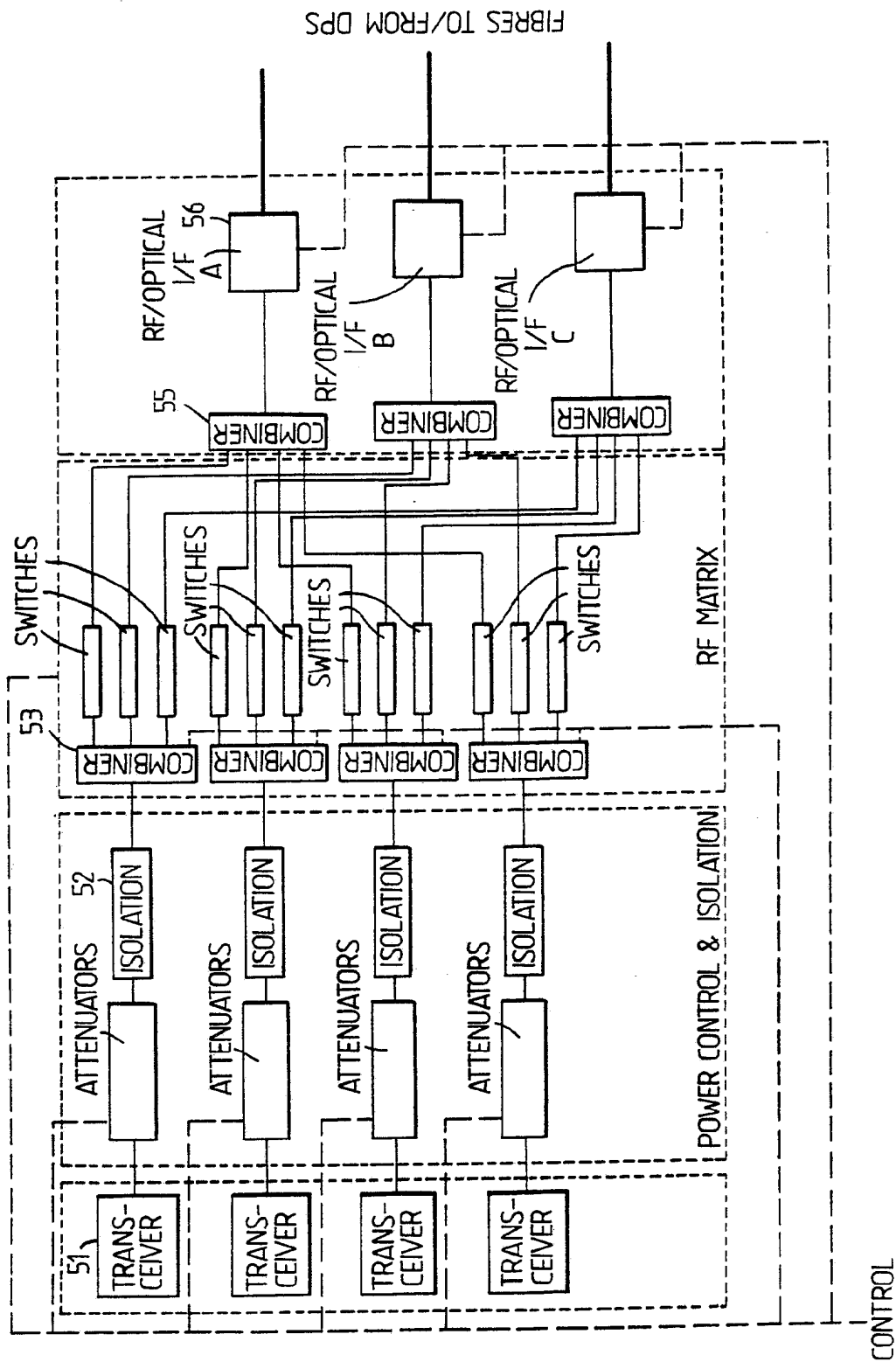
Fig.3.



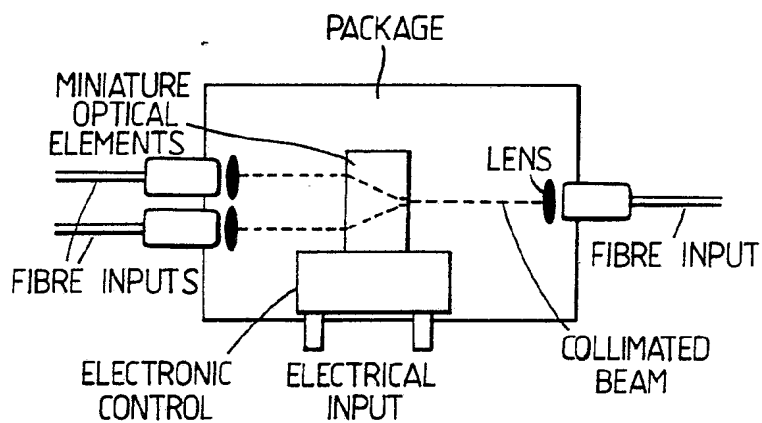
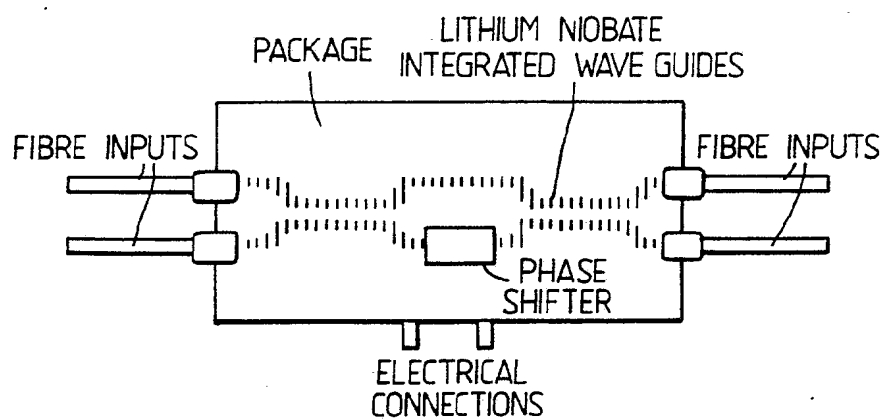
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Fig.4.



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Fig.5a.*Fig.5b.*

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 89/01341

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶ According to International Patent Classification (IPC) or to both National Classification and IPC IPC ⁵ : H 04 Q 7/04, H 04 B 7/26, H 04 M 1/72														
II. FIELDS SEARCHED <div style="text-align: center; margin-top: 10px;">Minimum Documentation Searched ⁷</div> <table style="width: 100%; border: none;"> <tr> <td style="width: 30%; border-bottom: 1px solid black; padding-bottom: 5px;">Classification System </td> <td style="border-bottom: 1px solid black; padding-bottom: 5px;">Classification Symbols</td> </tr> <tr> <td style="border: 1px solid black; padding: 5px; width: 30%;">IPC⁵</td> <td style="border: 1px solid black; padding: 5px; width: 70%;">H 04 B, H 04 M, H 04 Q</td> </tr> </table> <div style="text-align: center; margin-top: 10px;">Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸</div>			Classification System	Classification Symbols	IPC ⁵	H 04 B, H 04 M, H 04 Q								
Classification System	Classification Symbols													
IPC ⁵	H 04 B, H 04 M, H 04 Q													
III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹ <table style="width: 100%; border: none;"> <tr> <th style="width: 10%; border-bottom: 1px solid black; padding-bottom: 5px;">Category ⁹</th> <th style="width: 70%; border-bottom: 1px solid black; padding-bottom: 5px;">Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²</th> <th style="width: 20%; border-bottom: 1px solid black; padding-bottom: 5px;">Relevant to Claim No. ¹³</th> </tr> <tr> <td style="border: 1px solid black; text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="border: 1px solid black; padding: 5px;">Proceedings of the IEEE, volume 75, no. 4, April 1987, IEEE, (New York, US), D.C. Cox: "Universal digital portable radio communications", pages 436-477 see page 441, right-hand column, paragraph IV; page 452, right-hand column, paragraph e, lines 1-15; page 456, right-hand column, lines 19-25; page 457, right-hand column, paragraph 3 - page 459, right-hand column, paragraph c; page 465, left-hand column, paragraph c - right-hand column, paragraph 7 --</td> <td style="border: 1px solid black; text-align: center; vertical-align: top; padding: 5px;">1-5,11,12</td> </tr> <tr> <td style="border: 1px solid black; text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="border: 1px solid black; padding: 5px;">GB, A, 2138652 (STD. TELEPHONES AND CABLES) 24 October 1984 see page 1, lines 1-54; page 1, line 76 - page 2, line 10; page 2, lines 28-62; page 2, line 98 - page 3, line 35 --</td> <td style="border: 1px solid black; text-align: center; vertical-align: top; padding: 5px;">1,2,4</td> </tr> <tr> <td style="border: 1px solid black; text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="border: 1px solid black; padding: 5px;">EP, A, 0233963 (ANT) 2 September 1987 ./. --</td> <td style="border: 1px solid black; text-align: center; vertical-align: top; padding: 5px;">2-4,7,10,12</td> </tr> </table> <div style="margin-top: 10px;"> <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>¹⁰ Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&" document member of the same patent family</p> </div> </div> </div>			Category ⁹	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³	A	Proceedings of the IEEE, volume 75, no. 4, April 1987, IEEE, (New York, US), D.C. Cox: "Universal digital portable radio communications", pages 436-477 see page 441, right-hand column, paragraph IV; page 452, right-hand column, paragraph e, lines 1-15; page 456, right-hand column, lines 19-25; page 457, right-hand column, paragraph 3 - page 459, right-hand column, paragraph c; page 465, left-hand column, paragraph c - right-hand column, paragraph 7 --	1-5,11,12	A	GB, A, 2138652 (STD. TELEPHONES AND CABLES) 24 October 1984 see page 1, lines 1-54; page 1, line 76 - page 2, line 10; page 2, lines 28-62; page 2, line 98 - page 3, line 35 --	1,2,4	A	EP, A, 0233963 (ANT) 2 September 1987 ./. --	2-4,7,10,12
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A	EP, A, 0233963 (ANT) 2 September 1987 ./. --	2-4,7,10,12												
IV. CERTIFICATION <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border-bottom: 1px solid black; padding-bottom: 5px;">Date of the Actual Completion of the International Search</td> <td style="width: 50%; border-bottom: 1px solid black; padding-bottom: 5px;">Date of Mailing of this International Search Report</td> </tr> <tr> <td style="border: 1px solid black; text-align: center; padding: 5px;">8th February 1990</td> <td style="border: 1px solid black; text-align: center; padding: 5px;">01.03.90</td> </tr> <tr> <td style="border-bottom: 1px solid black; padding-bottom: 5px;">International Searching Authority</td> <td style="border-bottom: 1px solid black; padding-bottom: 5px;">Signature of Authorized Officer</td> </tr> <tr> <td style="border: 1px solid black; text-align: center; padding: 5px;">EUROPEAN PATENT OFFICE</td> <td style="border: 1px solid black; text-align: center; padding: 5px;"> T.K. WILLIS </td> </tr> </table>			Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	8th February 1990	01.03.90	International Searching Authority	Signature of Authorized Officer	EUROPEAN PATENT OFFICE	T.K. WILLIS				
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8th February 1990	01.03.90													
International Searching Authority	Signature of Authorized Officer													
EUROPEAN PATENT OFFICE	T.K. WILLIS													

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
	see page 6, lines 13-31; page 6, line 49 - page 7, line 5; page 7, line 42 - page 12, line 11 --	
A	DE, A, 3135231 (S.E.L.) 7 April 1983 see page 5, line 18 - page 6, line 15; page 7, lines 1-13; page 8, line 1 - page 9, line 20 --	1,2,5,8
A	EP, A, 0156336 (S.E.L.) 2 October 1985 see page 2, line 12 - page 4, line 27 --	1,2,4,10
A	Patent Abstracts of Japan, volume 5, no. 15, (E-43)(687), 29 January 1981, & JP, A, 55143854 (NIPPON DENSHIND DENWA KOSHA) 10 November 1980 -----	1,2,5,11

**ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.**

GB 8901341

SA 32257

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 21/02/90
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB-A- 2138652	24-10-84	CH-A- 664464	29-02-88
EP-A- 0233963	02-09-87	None	
DE-A- 3135231	07-04-83	None	
EP-A- 0156336	02-10-85	DE-A- 3411013	26-09-85
		AU-B- 578271	20-10-88
		AU-A- 3984585	26-09-85
		CA-A- 1232329	02-02-88
		JP-A- 61001126	07-01-86
		US-A- 4686671	11-08-87